specimen of *Cellepora fusca* from the 'Rattlesnake' collection and thirty or forty years old, I detected several minute tailed corpuscles, which can scarcely be any thing else than spermatozoa (see Plate XXVI. fig. 11).

EXPLANATION OF THE PLATES.

Each square or division contains the chitinous appendages of a single species. All the figures are magnified 115 diameters, and a scale =0·01 millim. is added.

Plate XXVI.

Fig. 1. *Cellepora albirostris*, mihi.
2. *C. albirostris?* (Bass Strait, Mr. Hincks.)
3. *C. hastigera.*
4. *C. columnaris.*
5. *C. polymorpha*, the massive branched form.
Fig. 6. *C. polymorpha*, var. *discoidea.*
7. *C. Jacksoniensis.*
8. *C. apiculata.*
9. *C. tridenticulata.*
10. *C. nodulosa.*
11. *C. fusca.*
12. *C. zamboangensis.*

Plate XXVII.

Fig. 1. *Cellepora ansata.*
2. *C. Eatonensis*, massive form. St. 149 D.
3. —— ——, incrusting form. St. 149 I.
4. *C. bicornis.*
5. *C. Eatonensis*, var. *magellanica.*
Fig. 6. *C. Eatonensis.*
7. *C. canaliculata.*
8. *C. bidenticulata.*
8*a*. —— —— (young).
9. *C. conica.*
10. *C. perlacea* (MS.).
11. *C. simonensis.*
12. *C. rudis.*

Observations on Ants, Bees, and Wasps.—Part VIII. By Sir John Lubbock, Bart., Pres. Linn. Soc., M.P., F.R.S., D.C.L., LL.D.

[Read June 2, 1881.]

Experiments with Light of different Wave-lengths.

In one of my former papers (Linnean Journ. vol. xiv. p. 278) I have given a series of experiments made on ants with light of different colors, in order, if possible, to determine whether ants have the power of distinguishing colors. For this purpose I utilized the dislike which ants, when in their nest, have for light. Not unnaturally, if a nest is uncovered, they think they are being attacked, and hasten to carry their young away to a darker and, as they suppose, a safer place. I satisfied myself, by hundreds of experiments, that if I exposed to light the greater part of a nest, but left any of it covered over, the young would certainly be conveyed to the dark part. In this manner I satisfied myself that the various rays of the spectrum act on them in a different manner from that in which they affect us; for instance, that ants are specially sensitive to the violet rays.

But I was anxious to go beyond this, and to attempt to determine how far their limits of vision are the same as ours. We all know that if a ray of white light is passed through a prism, it is broken up into a beautiful band of colors—the spectrum. To our eyes this spectrum is bounded by red at the one end and violet at the other, the edge being sharply marked at the red end, but less abruptly at the violet. But a ray of light contains, besides the rays visible to our eyes, others which are called, though not with absolute correctness, heat-rays and chemical rays. These, so far from falling within the limits of our vision, extend far beyond it, the heat-rays at the red, the chemical rays at the violet end.

I had already tried various experiments with spectra derived from sunlight; but, owing to the movement of the earth, they were not thoroughly satisfactory. Mr. Spottiswoode was also good enough to enable me to make some experiments with electric light, which have been already recorded; and I have now to bring before the Society some additional and much more complete experiments, which, through the kindness of Prof. Dewar, Prof. Tyndall, and the Board of Managers, to whom I beg to offer my most cordial thanks, I have been enabled to make in the Laboratory of the Royal Institution.

Prof. Dewar was also kind enough to test my glasses and solutions with reference to their power of transmitting color. Taking the wave-length of the extreme visible red as 760 and that of the extreme violet as 397, we have

760 to 647 give red.
647 ,, 585 ,, orange.
585 ,, 575 ,, yellow.
575 ,, 497 ,, green.
497 ,, 455 ,, blue.
445 ,, 397 ,, violet.

The result of his examination of my glasses and solutions was as follows:—

The light-yellow glass cut off the high end down to wave-length 442.

The dark-yellow glass cut off the high end down to wave-length 493.

The green glass cut off the high end down to wave-length 465, and also the red to 616.

The red glass cut off the high end down to wave-length 582.

The violet glass cut off the orange and yellow from wave-length 684 to 583, and a band between wave-lengths 543 and 516.

The purple glass cut off the high end down to wave-length 528.

The solution of chromate of potash cut off the high end to 507.

The saffron cut off the high end to about 473.

Blue fluid cut off the low end to 516.

Red fluid cut off the high end to 596.

In my previous experiments with colored spectra, the ants carried the pupæ out of the portion of the nest on which coloured light was thrown and deposited them against the wall of the nest; or, if I arranged a nest of *Formica fusca* so that it was entirely in the light, they carried them to one side or into one corner. It seemed to me, therefore, that it would be interesting so to arrange matters, that on quitting the spectrum, after passing through a dark space, the ants should encounter not a solid obstacle, but a barrier of light. With this object, I prepared some nests 12 inches long by 6 inches wide; and Mr. Cottrell kindly arranged for me at the Royal Institution on the 29th of June, by means of the electric light, two spectra, which were thrown by two glass prisms on to a table at an angle of about 45°. Each occupied about 6 inches square, and there was a space of about 2 inches between the red end of the one and the violet of the other, the more distant spectrum being a good deal the brightest.

Exp. 1.—In the light space I placed a nest of *Formica fusca*, 12 inches by 6, containing about 150 pupæ, and arranged it so that one end was distinctly beyond the limit of the violet visible to us, and all but to the edge of the green given by thalline paper*, and the other just beyond the visible red. The pupæ at first were almost all in or beyond the violet, but were carried into the dark space between the two spectra, the bright thalline band being avoided, but some pupæ being deposited in the red.

Exp. 2.—I then tried the same experiment with a nest of *Lasius niger*, in which there were many larvæ as well as pupæ. They were all at the commencement at the blue end of the nearer spectrum.

* If paper steeped in thalline is placed in the ultra-violet portion of the spectrum, it gives, with rays of a certain wave-length, a distinctly visible green colour, which therefore constitutes a green band.

The larvæ were left by themselves in the violet, while pupæ were ranged from the end of the green to that of the red inclusive.

Exp. 3.—Arranged a nest of *L. niger* as before; at the commencement the pupæ and larvæ were much scattered, being, however, less numerous in the violet and ultra-violet rays. Those in the ultra-violet rays were moved first, and were deposited, the larvæ in the violet, and the pupæ in the red.

Exp. 4.—Made the same experiment with another nest of *L. niger*. At the commencement the larvæ and pupæ were in the violet and ultra-violet portion, extending to double the distance from the visible end to the thalline band. The ants soon began bringing the pupæ to the red. Over part of the red I placed a piece of money. The pupæ were cleared from the ultra-violet first. That the pupæ were not put in the red for the sake of the red light was evident, because the space under the coin was even more crowded. The pupæ were heaped up in the dark as far as the thalline-band of the other spectrum. I then brought the second spectrum nearer to the first. The pupæ which thus found themselves in the thalline band were gradually moved into the dark.

Exp. 5.—Tried the same with another nest of *L. niger*. The pupæ were at first in the violet and ultra-violet about double as far as the thalline line, while most of the larvæ were in the green. The experiment began at 1.15. The furthest part was cleared first; and they were again brought principally into the yellow, red, and dark.

Again, I arranged them pretty equally from double the distance of the thalline from the violet as far as the blue of the other spectrum, most, however, being in the violet and blue and a few scattered all over.

The pupæ in the red were not moved. The others were carried beyond the thalline band into the yellow or red.

Exp. 6.—Repeated the same experiment. Begun it 11.15. Placed some pupæ in the red, some in the yellow, and a few scattered over the second spectrum; there were none in the nearer one.

They were all carried away from the red past the violet, and put down in the dark portion, or in the red and yellow, of the nearer spectrum.

These experiments surprised me much at the time, as I had expected the pupæ to be carried into the space between the two spectra; but it afterwards occurred to me that the ultra-violet rays probably extended further than I had supposed, so that even the part which lay beyond the thalline band contained enough rays to appear light to the ants. Hence perhaps they selected the red and yellow as a lesser evil.

Exp. 7.—I altered, therefore, the arrangement. Prof. Dewar very kindly prepared for me a condensed pure spectrum (showing the metallic lines) with a Siemens's machine, using glass lenses and a mirror to give a perpendicular incidence when thrown on the nest. I arranged the pupæ again in the ultra-violet as far as the edge of the fluorescent light shown with thalline paper. The pupæ were all again removed, and most of them placed just beyond the red, but none in the red or yellow.

Exp. 8.—Arranged the light as before, and placed the pupæ in the ultra-violet rays. In half an hour they were all cleared away and carried into the dark space beyond the red. We then turned the nest round and placed the part occupied by the pupæ again in the violet and ultra-violet. The light chanced to be so arranged that along one side of the nest was a line of shadow; and into this the pupæ were carried, all those in the ultra-violet being moved. We then shifted the nest a little, so that the violet and ultra-violet fell on some of the pupæ. These were then all carried into the dark, the ones in the ultra-violet being moved first.

It is noticeable that in these experiments with the vertical incidence there was less diffused light, and the pupæ were in no case carried into the red or yellow.

Exp. 9.—I arranged the light and the ants as before, placing the pupæ in the ultra-violet, some being distinctly beyond the bright thalline band. The ants at once began to remove them. At first many were deposited in the violet, some, however, being at once carried into the dark beyond the red. When all had been removed from the ultra-violet, they directed their attention to those in the violet, some being carried, as before, into the dark, some into the red and yellow. Again, when those in the violet had all been removed, they began on the pupæ in the red and yellow, and carried them also into the dark. This took nearly half an hour. As I had arranged the pupæ, and it might be said that they were awkwardly placed, we then turned the nest round, leaving the pupæ otherwise as they had been arranged by the ants; but the result of moving the nest was to bring some of them into the violet, though most were in the ultra-violet; while beyond them was a space of about an inch, which, in Prof. Dewar's opinion, was beyond the limit of the transparency of glass to the ultra-violet rays, and would therefore be as free from rays as the part beyond the red. They were, as before, all carried into the dark space beyond the red in about half an hour.

We then turned the glass round again, this time arranging the end about the length of the spectrum beyond the end of the violet visible to our eyes. They began clearing the thalline band, carrying some into the violet, but the majority away further from the spectrum. In a quarter of an hour the thalline band had been quite cleared; and in half an hour a band beyond, and equal to the thalline band, those in the violet being left untouched. After the pupæ in the ultra-violet portion had all been moved, those in the violet were also carried away and deposited about twice as far from the edge of the violet as the width of the bright thalline band.

Exp. 10.—Experimented again with the same arrangement as before, using another nest of *Lasius niger* and placing the pupæ in the violet and a little beyond. The ants at once began removing them into the dark, tunnelling into the heap, and then carrying away those in the ultra-violet first, although they were further off. In half an hour they had all been moved out of the violet and ultra-violet, about half being in the dark, and half having been provisionally placed in the red and yellow.

Exp. 11.—Same arrangement as before. The pupæ being placed all along one side of the nest, from the edge of the red to a distance beyond the violet as great as the whole length of the spectrum. I began at 4.15. By degrees they were all cleared away from the spectrum, except those in the violet, where indeed, and immediately outside of which, the others were placed. At 5, however, they began to carry them back into the red. At 5.45 the blue and violet were nearly cleared, the pupæ being placed in the red and yellow. At 6.15 they had all been brought from the violet and ultra-violet into the red and yellow.

I then shook up the pupæ so that they were arranged all along one side of the nest, and extended about an inch beyond the red. This excited them very much, and in less than ten minutes all those in the spectrum, and for about 6 inches beyond the violet, were moved, but at first put down anywhere, so that they were scattered all over the nest. This, however, lasted for a very short time, and they were all carried into the dark beyond the red or into the extreme end beyond the violet. At 7 they followed the line of the red at one end, coming about $\frac{1}{4}$ inch within it, which was not owing to want of room, as one side of the nest was almost unoccupied; at the other end they were all carried 3 inches beyond the end of the violet.

I then arranged the same ants in a wooden frame consisting of a base and two side walls, between which in the middle was a perpendicular sliding door. The pupæ had been arranged by the ants in the centre of the nest, so that some were on each side of the door. We then, by means of a strong induction-coil, threw a magnesium-spark on the nest from one side, and the light from a sodium-flame in a Bunsen burner on the other, the light being in each case stopped by the door, which was pressed close down on the nest. In this way the first half was illuminated by the one light, the second by the other, the apparatus being so arranged that the lights were equal to our eyes—that, however, given by the magnesium, consisting mainly of blue, violet, and ultra-violet rays, that of the sodium being very yellow and poor in chemical rays. In a quarter of an hour the pupæ were all carried into the yellow. The sodium light being the hotter of the two, to eliminate the action of heat I introduced a water-cell between the ants and the sodium-flame, and made the two sides as nearly as possible equally light to my eye. The pupæ, however, were again carried into the sodium side.

I repeated the same experiment as before, getting the magnesium-spark and the sodium-flame to the same degree of intensity, as nearly as my eye could judge, and interposing a water-screen between the sodium-flame and the ants. The temperature was tested by the thermometer; but I could distinguish no difference between the two sides. Still the ants preferred the sodium side. This I repeated twice. I then removed the magnesium-spark somewhat, so that the illumination on that side was very much fainter than on the other; still the pupæ were carried into the sodium-light. I then turned the nest round so as to bring them back into the magnesium. They were again carried to the sodium side.

Once more I repeated the same experiment. The light on the magnesium side was so faint that I could scarcely see the pupæ, those on the sodium side being quite plain. The thermometer showed no difference between the two sides. The pupæ were carried into the sodium-light. I then turned the nest round twice; but the pupæ were each time carried out of the magnesium-light.

These experiments seemed strongly to indicate, if not to prove, that ants were really sensitive to the ultra-violet rays. Now to these rays sulphate of quinine and bisulphide of carbon are extremely opaque, though perfectly transparent in the case of visible rays, and therefore to our eyes entirely colourless and transparent. If, therefore, the ants were really affected by the ultra-violet rays, then a cell containing a layer of sulphate of quinine or bisulphide of carbon would tend to darken the underlying space to their eyes, though to ours it would not do so. It will be remembered that if an opaque substance is placed over a part of a glass nest, other things being equal, the ants always congregate under it; and that if substances of different opacity are placed on different parts of a nest, they collect under that which seems to them most opaque.

Over one of my nests of *Formica fusca*, therefore, I placed two pieces of dark-violet glass 4 inches by 2 inches; and over one of them I placed a cell containing a layer of bisulphide of carbon, an inch thick, slightly coloured with iodine. In all these experiments, when I moved the liquids or glasses, I gave the advantage, if any, to the one under which experience showed that the ants were least likely to congregate. The ants all collected under the glass over which was the bisulphide of carbon.

I then thought that though no doubt the iodine rendered the bisulphide more completely impervious to the ultra-violet rays, I would try the effect of it when pure and perfectly colourless. I therefore tried the same experiment with pure bisulphide, moving the two glasses from time to time in such a manner that the ants had to pass the first violet glass in order to reach that over which was the bisulphide.

At 8.30 the ants were all under the glass over which was the bisulphide of carbon: I then changed the position.
8.45 ditto ditto ditto.
9 ditto ditto ditto.
9.15 ditto ditto ditto.

Although the bisulphide of carbon is so perfectly transparent, I then thought I would try it without the violet glass. I therefore covered part of the nest with violet glass, a part with a layer of bisulphide of carbon, moving them from time to time as before.

At 9.45 the ants were all under the bisulphide: I then changed the position.
10.15 ditto ditto ditto.
10.45 ditto ditto ditto.
11.15 ditto ditto ditto.

I then reduced the thickness of the layer of bisulphide to $\frac{4}{10}$ of an inch.

At 1.30 the ants were all under the bisulphide: I then changed the position.
2 ditto ditto ditto.
2.30 ditto ditto ditto.
3 ditto ditto ditto.

Then thinking that possibly it might make a difference, the one shelter being a plate of glass and the other a liquid, I tried two similar bottles, one containing water and the other bisulphide of carbon; but in every case the ants went under the bisulphide of carbon. On the other hand, when I used a solution of ammonio-sulphate of copper so deep in colour that the ants were only just visible through it, the ants went under the coloured liquid.

Oct. 10. I uncovered the nest at 7 A.M., giving the ants an option between the bisulphide and a solution of ammonio-sulphate of copper.

At 7.30 the ants were all under the solution of ammonio-sulphate of copper. Changed the places.
8 ditto ditto ditto.
8.15 ditto ditto ditto.

I then replaced the solution of sulphate of copper by one of carmine so deep that the ants could only just be seen through it.

At 8.30 they were under the carmine. I shifted the carmine and bisulphide.
8.45 ditto ditto ditto.
9 ditto ditto ditto.
9.15 ditto ditto ditto.
9.30 ditto ditto ditto.

I now took a bright-green solution of chlorate of copper:—

At 10 they were under the chlorate of copper. I shifted the liquids.
10.15 ditto ditto ditto.
12.30 ditto ditto ditto.
12.45 ditto ditto ditta.

Subsequently I used saffron instead of the chlorate of copper:—

At 11 they were under the saffron. I shifted the liquids.
11.15 ditto ditto ditto.
11.25 ditto ditto ditto.
11.35 ditto ditto ditto.

I now took successively red, yellow, and green glass; but in every case the ants preferred the glass to the bisulphide. Although, therefore, it would seem from the previous experiments that the bisulphide darkened the nests to the ants more than violet glass, it would appear to do so less than red, green, or yellow.

I now made some experiments in order, if possible, to determine whether the reason why the ants avoided the violet glass was because they disliked the colour violet, or whether it was because the violet glass transmitted more of the ultra-violet rays.

For this purpose I placed a layer of the bisulphide of carbon over a piece of violet glass. By this arrangement I got the violet without the ultra-violet rays; and I then contrasted this combination with other coloured media.

First, I took a solution of bichromate of potash (bright orange), and placed it on a part of the nest side by side with the violet glass and bisulphide of carbon. I should add that the bichromate of potash also cuts off the ultra-violet rays. In all the following observations I changed the position after each observation.

At 1.30 P.M. the ants were under the bichromate.
3 „ „ half under the bichromate and half under the violet glass and bisulphide.
8 A.M. „ „ under the bichromate.
8.30 „ „ under the violet glass and bisulphide.
9 „ „ half under each.
9.30 „ „ some under each, but most under the violet glass and bisulphide.
9.45 „ „ half under each.
10 „ „ „ „

In this case, therefore, though without the layer of bisulphide the violet glass would always have been avoided, the result of placing the bisulphide over the violet glass was that the ants did not care much whether they were under the violet glass or under the bichromate of potash.

I now took the same solution of carmine which I had already used.

10. The ants were under the carmine.
10.15 „ „ „
10.30 „ most under the carmine, but some under the violet.
10.45 „ under the carmine.
11 „ most under the carmine, but some under the violet.

Here, then, again the bisulphide made a distinct difference, though not so much so as with the bichromate of potash.

I now took the solution of chlorate of copper already used.

1. About half the ants were under each.
1.30. The greater number were under the violet glass and bisulphide.
2. ditto ditto ditto.
2.30. ditto ditto ditto.
3. Almost all were under the violet glass and bisulphide.

Here, then, the addition of the bisulphide caused the violet glass to be distinctly preferred to the chlorate of copper.

I then took a solution of sulphate of nickel, almost exactly the same tint, or a shade paler than, the chlorate of copper.

At 3.45 the ants were under the violet glass and bisulphide.
4 ditto ditto ditto.
5 ditto ditto ditto.

Oct 18.
7 A.M. ditto ditto ditto.
8. About half of the ants were under each.

Here the same result was even more marked.

I then took some saffron 1 inch in thickness and of a deep-yellow colour.

12.45. The ants were about half under each.
1. Most of the ants were under the violet glass and bisulphide.
1.15. ditto ditto ditto.
2. Most of the ants were under the saffron.

Here, again, we have the same result.

I then tried the different-coloured glasses, all of which, as I had previously found, are unmistakably preferred to the violet. It remained to see what effect placing the bisulphide of carbon on the violet would have.

First, I placed side by side, as usual, a piece of green glass and the violet glass covered with bisulphide of carbon:—

1st exp. Half of the ants were under each.
2nd „ They were under the violet glass and bisulphide.
3rd „ „ „ „
4th „ Most of them „ „
5th „ „ „ „

Next, I tried pale-yellow glass.

1st obs. The ants were almost all under the violet glass and bisulphide.
2nd „ About three quarters were „ „
3rd „ They were all „ „
4th „ About half were under each.

I then took the dark-yellow glass.

1st obs. About half the ants were under the yellow glass and half under the violet glass and bisulphide.
2nd „ Most of them were under the violet glass and bisulphide.
3rd „ „ „ yellow glass.
4th „ „ „ violet glass and bisulphide.
5th „ About half under each.

I now took deep-red glass.

1st obs. The ants were under the red glass.
2nd „ Half of the ants were under each.
3rd „ Most of the ants were under violet glass and bisulphide.
4th „ Half were under each.

It seemed evident, therefore, that while if violet glass alone was placed side by side with red, yellow, or green, the ants greatly preferred any of the latter, on the other hand, if a layer of bisulphide of carbon, which to our eyes is perfectly transparent, was placed over the violet glass, they then went as readily, or even more readily, under it than under other colours.

In order to be sure that it was not the mere presence of a fluid, or the two layers of glass, to which this was due, I thought it would be well to try a similar series of experiments, using, however, a layer of similar thickness (1 inch) of water coloured light blue by ammonio-sulphate of copper.

I therefore took again the piece of violet glass, over which I placed a flat-sided bottle, about 1 inch thick, containing a light-blue solution of ammonio-sulphate of copper; and, in contrast with it, I used the same coloured glasses as before.

First, I took the red glass.

Observation 1. Some of the ants were under each, but most under the red glass.
" 2. All under the red glass.
" 3. Almost all under the red.
" 4. " "
" 5. " "

I now took the green glass.

Observation 1. Almost all were under the green.
" 2. All were under the green.
" 3. Two thirds were under the green.
" 4. All " "
" 5. " " "
" 6. " " "

These experiments were made on a gloomy day; so I repeated them on a bright one, when the contrast was more marked.

Observation 7. All were under the green glass.
" 8. " "
" 9. " " except two or three.
" 10. " "
" 11. " "
" 12. " "

I now took the dark-yellow glass.

Observation 1. All were under the yellow glass.
" 2. " "
" 3. " "
" 4. " "

I now took the light-yellow glass.

Observation 1. They were all under the light-yellow glass.
" 2. " " "
" 3. " " "
" 4. " " "

These experiments seem to demonstrate that in the previous series the ants were really influenced by some property inherent in the bisulphide of carbon, and which affected their eyes, though it was insensible to ours.

I then thought it would be interesting to use, instead of the bisulphide, a solution of sulphate of quinine ($\frac{1}{2}$ dr. to 4 ounces), which differs from it in many points, but agrees in cutting off the ultra-violet rays. I used, as before, a layer about an inch thick, which I placed over violet glass, and then placed by its side the same coloured glasses as before.

First, I took the red glass.

Obs. 1. About half the ants were under each.
„ 2. Most of them were under the red glass.
„ 3. About half under each; rather more under the violet glass and sulphate of quinine than under the red glass.
„ 4. ditto ditto ditto.

I now took the dark-yellow glass instead of the red.

Obs. 1. Most of the ants were under the violet glass and sulphate of quinine.
„ 2. All ” ” ”
„ 3. ” ” ” ”
„ 4. ” ” ” yellow glass.
„ 5. ” ” ” ”
„ 6. All of the ants were under the violet glass and sulphate of quinine.
„ 7. About half under each.
„ 8. Rather more under the violet glass and sulphate of quinine than under the yellow glass.

I then took the light-yellow glass instead of the dark.

Obs. 1. The ants were all under the violet glass and sulphate of quinine.
„ 2. Rather more than half under the yellow glass.
„ 3. Almost all under the violet glass and sulphate of quinine.
„ 4. All ” ” ”

I then took the green glass instead of the yellow.

Obs. 1. They were under the violet glass and sulphate of quinine.
„ 2. ” ” ”
„ 3. About half under each.
„ 4. About three quarters under the green glass.
„ 5. Almost all under the violet glass and sulphate of quinine.

I then tried similar experiments with a saturated solution of chrome alum and chromium chloride. These are dark greenish blue, very opaque to the visible light-rays, but transparent to the ultra-violet. I used a layer ¼ inch thick, which was still so dark that I could not see the ants through it; and for comparison, a solution 1 inch thick of bisulphide of carbon, moving them after each observation as before.

Exp. 1. The ants were under the bisulphide of carbon.
,, 2. ,, ,, ,,
,, 3. Most ,, ,, ,,
,, 4. All but three ,, ,, ,,
,, 5. All ,, ,, ,,

I now took chromium chloride instead of chrome alum.

Exp. 1. Most were under the bisulphide of carbon.
,, 2. All ,, ,, ,,
,, 3. Almost all ,, ,, ,,
,, 4. About three fourths were under the chromium chloride.
,, 5. All were under the chromium chloride.
,, 6. About two thirds ,, ,,
,, 7. About one half under each.
,, 8. All under the bisulphide of carbon.
,, 9. About three fourths under the bisulphide of carbon.
,, 10. About half ,, ,, ,,
,, 11. All under the chrome alum.
,, 12. ,, bisulphide of carbon.

Thus, then, while if the ants have to choose between the violet and other coloured glasses, they will always prefer one of the latter, the effect of putting over the violet glass a layer either of sulphate of quinine or bisulphide of carbon, both of which are quite transparent, but both of which cut off the ultra-violet rays, is to make the violet glass seem to the ants as good a shelter as any of the other glasses. This seems to me strong evidence that the ultra-violet rays are visible to the ants.

Prof. Paul Bert has made ('Archiv de Physiol.' 1869, p. 547) some very interesting experiments on a small freshwater Crustacean belonging to the genus *Daphnia*, from which he concludes that they perceive all the colours known to us, being, however, specially sensitive to the yellow and green, and that their limits of vision are the same as ours.

Nay, he even goes further than this, and feels justified in concluding from the experience of two widely divergent species—Man and *Daphnia*—that the limits of vision would be the same in all cases.

His words are :—

A. " Tous les animaux voient les rayons spectraux que nous voyons."

B. " Ils ne voient aucun de ceux que nous ne voyons pas."

C. " Dans l'étendue de la région visible, les différences entre les pouvoirs éclairants des différents rayons coloriés sont les mêmes pour eux et pour nous."

He adds, that " puisque les limites de visibilités semblent être les mêmes pour les animaux et pour nous, ne trouvons-nous pas là une raison de plus pour supposer que le rôle des milieux de l'œil est tout-à-fait secondaire, est que la visibilité tient à l'impressionnabilité de l'appareil nerveux lui-même ? "

Such a generalization would seem to rest on but a slight foundation ; and I may add that I have made some experiments myself on Daphnias which do not agree with those of M. Bert. I hope on some future occasion to have the honour of laying them before the Society.

At any rate, it seems to me that the preceding evidence strongly indicates that ants perceive the ultra-violet rays. Now, as every ray of homogeneous light which we can perceive at all appears to us as a distinct colour, it seems probable that these ultra-violet rays must make themselves apparent to the ants as a distinct and separate colour (of which we can form no idea), but as unlike the rest as red is from yellow, or green from violet. The question also arises whether white light to these insects would differ from our white light in containing this additional colour. At any rate, as few of the colours in nature are pure colours, but almost all arise from the combination of rays of different wave-lengths, and as in such cases the visible resultant would be composed not only of the rays which we see, but of these and the ultra-violet, it would appear that the colours of objects and the general aspect of nature must present to them a very different appearance from what it does to us.

Sense of Direction.

In continuation of the experiments recorded in my last paper (Linnean Journ. vol. xv. p. 177), I caused to be constructed a circular table 18 inches in diameter, the arrangement of which was kindly devised for me by Mr. Francis Galton. It consisted, as shown in figs. 1 and 2, of three concentric pieces—a central F G, an intermediate D E, H I, and an outer piece B C, K L, each of these three pieces being capable of separate rotation.

Fig. 1.

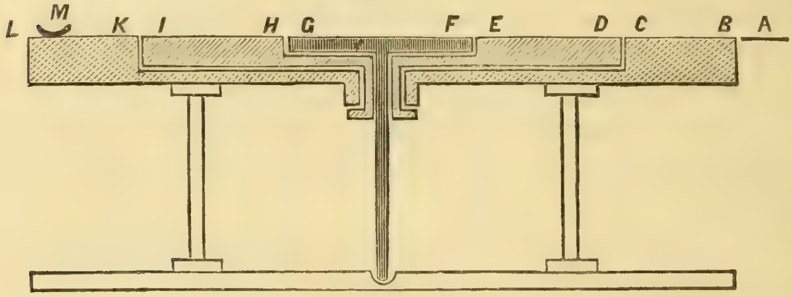
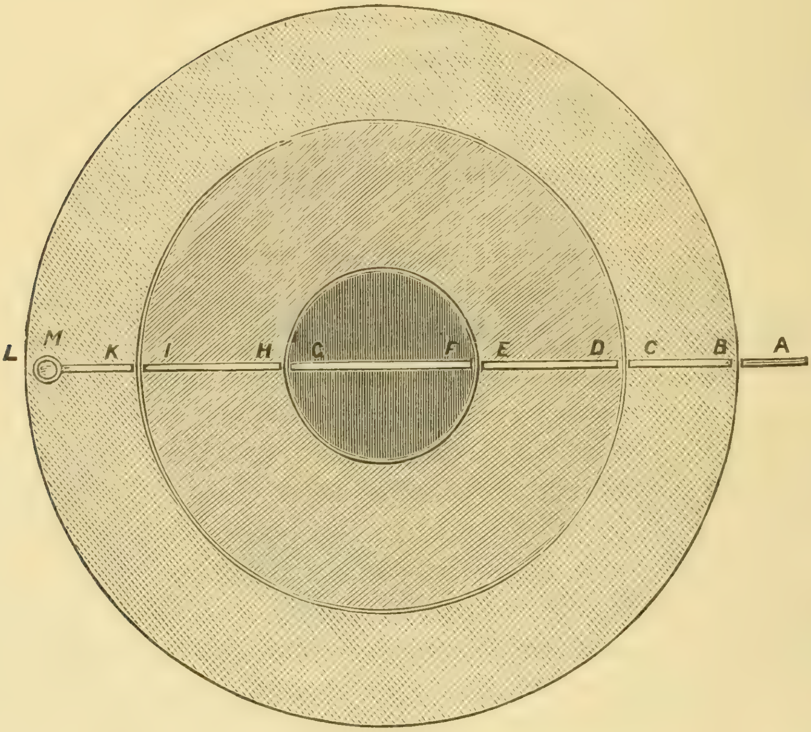


Fig. 2.



I then connected the table with a nest of *Lasius niger* by a paper bridge A, and also made a paper path across the table, as shown in fig. 2, divided into five pieces corresponding to the divisions of the table. This I did because I found that the ants wandered less if they were provided with a paper road than if they walked actually on the wood itself. I then placed a cup containing larvæ on the table at B, and put an ant on the larvæ. She at once picked one up, and, with some little guidance from me, carried it off to the nest, returning at once for another, bringing some friends with her to help. When she knew her way, I gradually moved the cup across the table along the paper bridge to M. After a while the ants came to know the way quite well, and passed to and fro quite straight along the paper path from the nest to the larvæ at M. Having thus established a service of ants, I tried the following experiments:—

1. I removed the piece of paper G F. This disturbed them; but they very soon reestablished the chain.

2. I turned round the central piece of the table G F, so that the paper G F was reversed, G being where F had been, and *vice versâ.* This did not seem to disconcert the ants at all.

3. When the ants were between I and B, I rotated the outer circle of the table halfway round, which of course carried the cup containing the larvæ from L to B. The ants took no notice of this, but went straight to L.

4. When the ants were between I and B, I rotated the table several times, bringing it finally to the original position. This disturbed them a good deal; but eventually they all continued their course to L.

5. When the ants were between I and D, I half rotated the two centre parts of the table, the result of which, of course, was that the ant was moving away from, instead of towards, the nest. In every case the ants turned round too, so as duly to reach L. So also those which were on their way from the nest to the larvæ turned in the same manner.

6. When the ants were between I and D, I half rotated the whole table. Again the ants turned round too, though of course in this case, when they reached the place where L had been, the cup with the larvæ was behind them at B.

These two experiments, though quite in accordance with those previously made, puzzled me a good deal. Experiment 3, as well as those recorded in previous papers, seemed to show that ants were little guided in such cases by the position of surrounding objects. However, I was anxious to test this.

7. Accordingly I took a round box and placed it upside down on the table, having cut two niches, one at each side, where it lay on the paper path, so as to afford a passage for the ants, as in the experiments recorded in my previous paper; but on this occasion I left the lid on, cutting, however, a hole through which I could watch the result. In this case, therefore, the surrounding objects, *i. e.*

the walls of the box, turned round with the table. Then, as before, when the ants were between I and D, I turned the table half round. The results were as follow :—

	Ants which turned.	Ants which did not turn.
Exp. 1.	1	2
„ 2.	1	1
„ 3.	1	1
„ 4.	4	2
„ 5.	0	1
„ 6.	0	1
„ 7.	0	3
„ 8.	1	1
„ 9.	0	1
„ 10.	2	2
„ 11.	1	1
„ 12.	0	3
	11	19

In this case, then, only 11 ants turned; and as 4 of them were together, it is possible that 3 simply followed the first. Moreover, the ants which turned did so with much more hesitation and less immediately.

8. For comparison, I then again tried the same experiment, but without the box. The results were as follows:—

	Ants which turned.	Ants which did not turn.
Obs. 1.	3	0
„ 2.	3	0
„ 3.	3	1 ?
„ 4.	3	0
„ 5.	4	0
„ 6.	4	0
	20	1 ?

Under these circumstances, therefore, all the ants but one certainly turned, and her movements were undecided.

From these last two experiments it is obvious that the presence of the box greatly affected the result, and yet the previous results made it difficult to suppose that the ants noticed any objects so distant as the walls of the rooms, or even as I was myself. The result surprised me considerably; but I think the explanation is given by the following experiments.

I again put some larvæ in a cup, which I placed in the centre of the table; and I let out an ant which I had imprisoned after the previous experiments, placing her in the cup; she carried off a larva to the nest and soon returned. When she was again in the cup, I rotated the table; when she came out she seemed a little surprised; but after walking once round the cup, started off along the paper bridge straight home. When she returned to the cup, I again half rotated the table. This time she went back quite straight. When she had come again, I once more half rotated the table; she returned quite straight. Again the same happened. A second ant then came: I half rotated the table as before. She went wrong for about an inch and a half, but then turned round and went straight home.

I was working by the light of two candles which were on the nest-side of the table. The next time the two ants came, I half rotated the table as before and moved the candles to the far side. This time the ants were deceived, and followed the paper bridge to the end of the table furthest from the nest. This I repeated a second time, with the same result. I then turned the table as before without altering the lights, and the ants (four of them) went back all right. I then again turned the table, altering the lights, and the ant went wrong.

I then altered the lights without rotating the table: the first ant went wrong; the second right; the third wrong; the fourth wrong; the fifth hesitated some seconds, and then went wrong; the sixth right; the seventh went all but to the edge the wrong way, but, after various wanderings, at last went right. When, therefore, the direction of the light was changed, but every thing else left as before, out of seven ants, five were deceived and went in the wrong direction.

After an interval of a week, on March 25, I arranged the nest and the rotating table as before, and let out three ants which I I had imprisoned on the 19th, and which knew their way. I put them on the larvæ at M as before. The paper pathway had been left untouched. The ants examined the larvæ and then went straight home along the paper path; but, to my surprise, only one of them carried off a larva. Nevertheless they had evidently taken the news to the nest; for the ants at once began coming to the cup in considerable numbers and carrying off the larvæ. I do not altogether understand this proceeding, and unluckily had not marked the first three ants; so that I cannot tell whether they brought or sent their friends. It seems possible that they felt unequal to the exertion of carrying a burthen to the nest until they had had some food.

When the ants were fairly at work, I turned the table 90 degrees. In this case eight ants continued their march along the paper, while two turned back; but none left the paper, and went across the table straight for the larvæ.

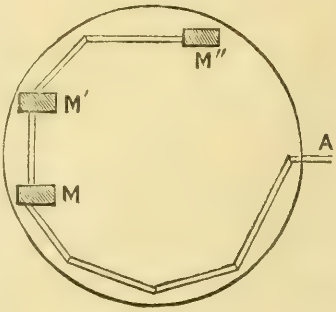
I then stopped the experiment for a while, so that the excitement might subside; as when the ants become too numerous it is not so easy to watch them.

When all was quiet, I put the cup with the larvæ on the middle of the table, and covered the greater part of the table with the box as before (p. 379). When the ants were leaving the cup on their way home, I then, as before, turned the table half round.

Under these circumstances, however, instead of turning as in the previous experiment, ten ants, one after another, continued their course, thus coming out of the box at the end furthest from the nest. When ten ants successively had, under these circumstances, gone wrong, I then, to make the experiment complete, tried it again, every thing being the same, except that there was no box. Under these circumstances five ants, one after the other, turned directly the table was rotated. It seems clear, therefore, that in determining their course the ants are greatly influenced by the direction of the light.

March 27. I let out two ants imprisoned on the 25th, and placed them on the larvæ, which I put on a column 7 inches high, covered with blue paper, and communicating with the nest by the paper path (A, fig. 3) arranged as usual, but supported on pins. At first I arranged it as shown below, placing the larvæ at M, so that the ants, on arriving at the larvæ, made nearly a semicircle round the edge of the table. I then gradually moved the larvæ to M′ and afterwards to M″. The ants, however, obviously knew that they were going unnecessarily round. They ran along the paper bridge in a very undecided manner, continually turning round and often coming down the pins; while in

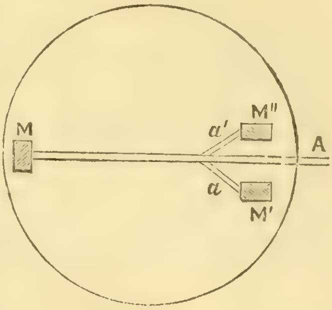
Fig. 3.



returning to the nest they persistently came down the side of the pillar nearest to the nest, though we repeatedly attempted to guide them the other way. Even when placed on the paper bridge between M and M′, they were very dissatisfied. In fact it was obvious that they knew they were being sent a long way round, and were attempting to make a shorter cut.

I then again placed the larvæ at M, and when the ants were once more going to and fro regularly along the paper path, I altered the position to M′, placing the edge of the pillar, which the ants had been accustomed to ascend, towards the paper bridge, connecting it with the original bridge by a side-bridge *a*, M being an inch from the original bridge. Under these circumstances three ants ran on to M; then two found their way over the bridge *a* to M′. Of the next ten ants, five went to M and five over *a* to M′. The next ten all went over the paper bridge *a* to M′.

Fig. 4.



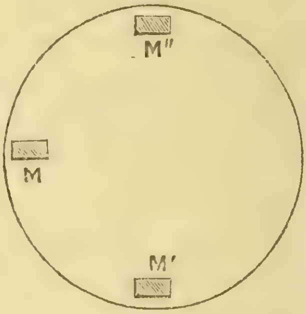
I then put the pillar and the larvæ on the other side of the original paper path at M″ connected with the main path by a short bridge *a′*, and took for *a′* a new piece of paper, so that scent would be no guide. I left the little bridge *a* in its place. The ants went as follows:—

To M″.	M′.	M.
1	0	0
1	0	1
1	0	1
1	0	1
1	1	1
0	0	1
1	0	0
1	0	0
1	0	0
1	0	0
1	1	0
1	1	0
1	0	0
12	3	5

It seems clear, therefore, that though the ants did not trust so much to their eyes as a man would have done under similar circumstances, yet that they were to some extent guided by sight.

I then removed all the paper pathways and put the pillar to M. Of the two first ants which came to the table, the first found the pillar in 5 minutes, the second, after wandering about for a quarter of an hour, gave the search up in despair, and went home. I then moved the pillar to M′ and watched the next ant that came on to the table; she found it in a minute or two. I then moved it to M″. Two ants came together. One found the pillar in 7 minutes; the other took no less than 25. Obviously, therefore, though it seems clear that they are helped by sight, still these last observations support those previously recorded, and show that in finding their way they do not derive by any means so much assistance from their eyes as we should under corresponding circumstances.

Fig. 5.



Production of Queens.

I have mentioned in one of my previous papers that queens have never (so far, at least, as I had been able to observe) been produced in my nests. I was therefore much interested last year (1880) to find five queens developed in one of my nests of *Formica fusca*. The nest had been under observation since April 1879, and the eggs therefore must have been laid in captivity. The nest had been richly supplied with animal food, and this may possibly account for the fact.

It is known that bees, by difference of food &c., possess the power of obtaining at will from the same eggs either queens or ordinary workers. Mr. Dewitz *, however, is of opinion that among ants, on the contrary, the queens and workers are produced from different kinds of eggs. He remarks that it is very difficult to understand how the instinct, if it is to be called instinct, which would enable the working ants to make this difference can have arisen. This is no doubt true; but it seems to me quite as difficult to understand how the queens, which must have originally laid only queen eggs and male eggs, can have come to produce a third class. Moreover, however great the difficulty may be to

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* Zeit. für wiss. Zool. 1878, p. 101.

understand how the ants can have learnt to produce queens and workers from one kind of egg, the same difficulty exists almost to the same extent in bees, which, as Mr. Dewitz admits, do possess the power. Moreover, it seems to me very unlikely that the result is produced in one way in the case of bees, and in another in that of ants. It is also a strong argument that in all my nests, though thousands of workers and males have been produced, I have never observed a queen to be so until this year. On the whole, then, though I differ from so excellent a naturalist with much hesitation, I cannot but think that ants, like bees, possess the power of developing a given egg into either a queen or a worker.

Affection and Kindness.

While I was watching one of my nests of *Formica fusca* on the 23rd of January last (1881), I perceived a poor ant lying on her back and quite unable to move. The legs were in cramped attitudes, and the two antennæ rolled up in spirals. She was, of course, altogether unable to feed herself. After this I kept my eye on her. Several times I tried uncovering the part of the nest where she was. The other ants soon carried her into the shaded part. On the 4th March the ants were all out of the nest, probably for fresh air, and had collected together in a corner of the box; they had not, however, forgotten her, but had carried her with them. I took off the glass lid of the box, and after a while they returned as usual to the nest, taking her in again. On the 5th March she was still alive; but on 15th, notwithstanding all their care, she was dead.

Longevity of Ants.

In my previous paper I have called attention to the considerable age attained by my ants; and I may perhaps be permitted to repeat here, *mutatis mutandis*, a paragraph from my last communication with reference to my most aged specimens, most of those mentioned last year being still alive. One of my nests of *Formica fusca* was brought from the woods in December 1874*. It then contained two queens, both of which are now still alive. I am disposed to think that some of the workers now in the nest were among those originally captured, the mortality after the first few weeks having been but small. This, of course, I cannot prove. The queens, however, are certainly seven, and probably eight,

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* They are still alive and well, Sept. 25, 1881.

years old. In the following nests, viz. another nest of *Formica fusca*, which I brought in on the 6th June 1875, one of *Lasius niger* on the 25th July 1875[*], and of *Formica cinerea* on the 29th November 1875, there were no queens; and, as already mentioned, no workers have been produced. Those now living are therefore the original ones; and they must be between six and seven years old. I may add that in these nests there have been for the last year very few deaths[†].

In conclusion, I may place on record a new species of mite which I have found in nests of *Lasius flavus*, and of which Mr. Michael has been good enough to draw up the following description.

UROPODA FORMICARIÆ, sp. nov.

This species, although it falls strictly within the genus *Uropoda*, and not within Kramer's genus *Trachynotus* as defined by that writer, still in most respects, except the very distinctions upon which the genus is founded, resembles *Trachynotus pyriformis* (Kramer) more closely than it does any other recorded species. It is, however, decidedly different; and is characterized by the squareness of its abdomen, the thickness and roughness of its chitinous dermal skeleton, and *especially* by the powerful chitinous rdiges or wing-like expansions on the lateral surface between the second and third pair of legs.

Length, ♂ and ♀, about ·95 millim.
Breadth ,, ,, ·55 ,,

The abdomen is almost square, but somewhat longer than broad, and slightly narrowed at its junction with the cephalothorax, from which it is not plainly distinguished. The extreme edge is a strong chitinous ridge bordered with a thick fringe of short, stout, curved hairs, as in *T. pyriformis*. The dorsal surface of the cephalothorax is also narrowed towards the front, and has a curved anterior margin bent down so as to protect the mouth, as in that species; it bears a few of the same kind of hairs as the abdomen, and has a chitinous thickening at each side. The abdomen rises almost perpendicularly from the marginal ridge. There is a central depression occupying the posterior half, or rather more than half of the abdomen; and at the bottom of this depression are transverse ridges, the hinder ones nearly straight, and the anterior ones bent

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[*] The last of these died on June 15, 1881.

[†] These ants died off somewhat rapidly, the last on July 23, 1881.

in the middle, the central point being forward; at the sides of, but not in, this depression, are two chitinous blocks which seem to form a starting-point for the ridges. Anterior to this depression the central portion of the creature, *i. e.* its longitudinal dorsal axis, is higher in level than in parts nearer the margin, and forms an irregular triangle of rough chitine. A broad chitinous plate or ridge projects on each side above the second leg, and between that and the third, evidently for their protection; it is probably flexible at the will of the creature, as in the genus *Oribates*.

The sternal surface has strongly marked depressions for the reception of the legs. The coxæ of the first pair of legs are largely developed, flattened, almost touch in the median line, and nearly conceal the mouth, as in the typical *Uropodas*. The genital opening of the male is rather large, round, and placed centrally between the coxæ of the second pair of legs. The female appears only to be distinguished from the male by being more strongly chitinized, and by the conspicuous valval plate which occupies the whole space between the coxæ of the second and third pairs of legs and extends beyond both.

The nymph is less square in the abdomen than the adult, and the border of hairs is absent; the margin is somewhat undulated, the concave undulations being so placed as to give free action to the legs when raised; the central depression of the abdomen is far less marked than in the adult; a slight ridge runs all round the dorsal surface a little within the margin; four ridges, two anterior and two posterior, run from the circumscribing ridge to a raised ellipse in the centre; there are not any plates for the protection of the legs, and the coxæ of the first pair are not flattened as in the adult.

This mite lives in the nests of *Formica flava*.